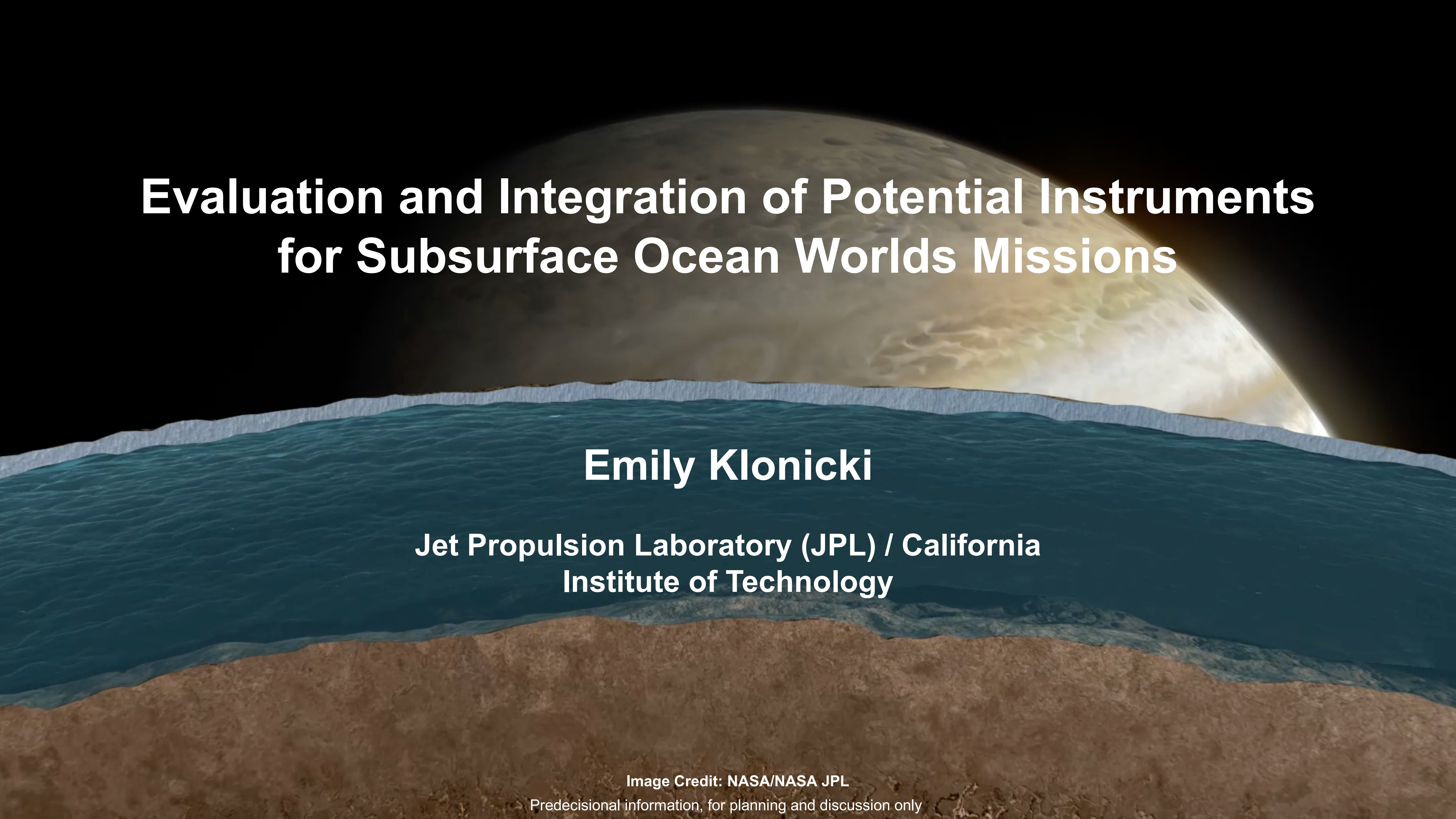


Evaluation and Integration of Potential Instruments for Subsurface Ocean Worlds Missions

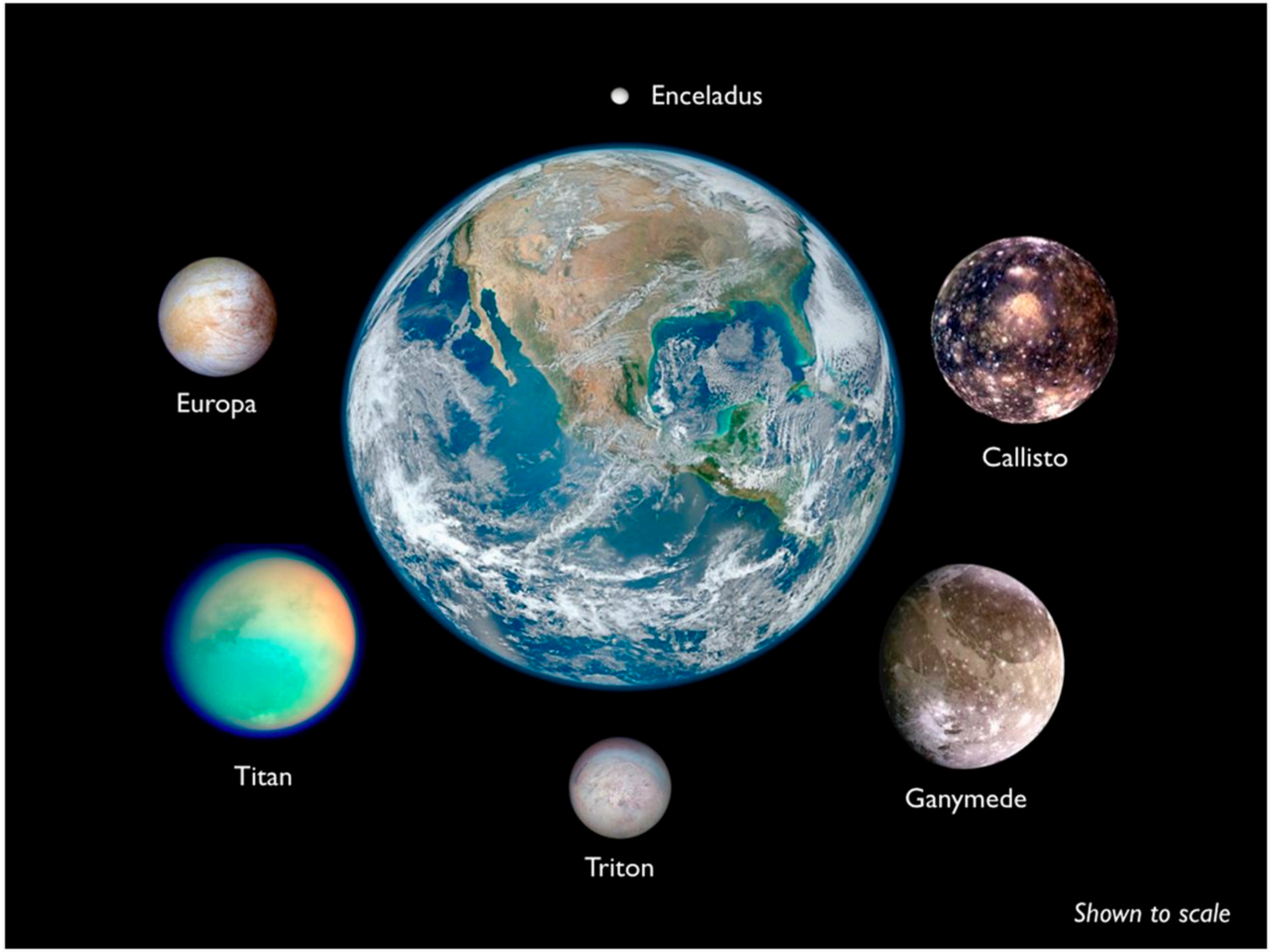
Emily Klonicki

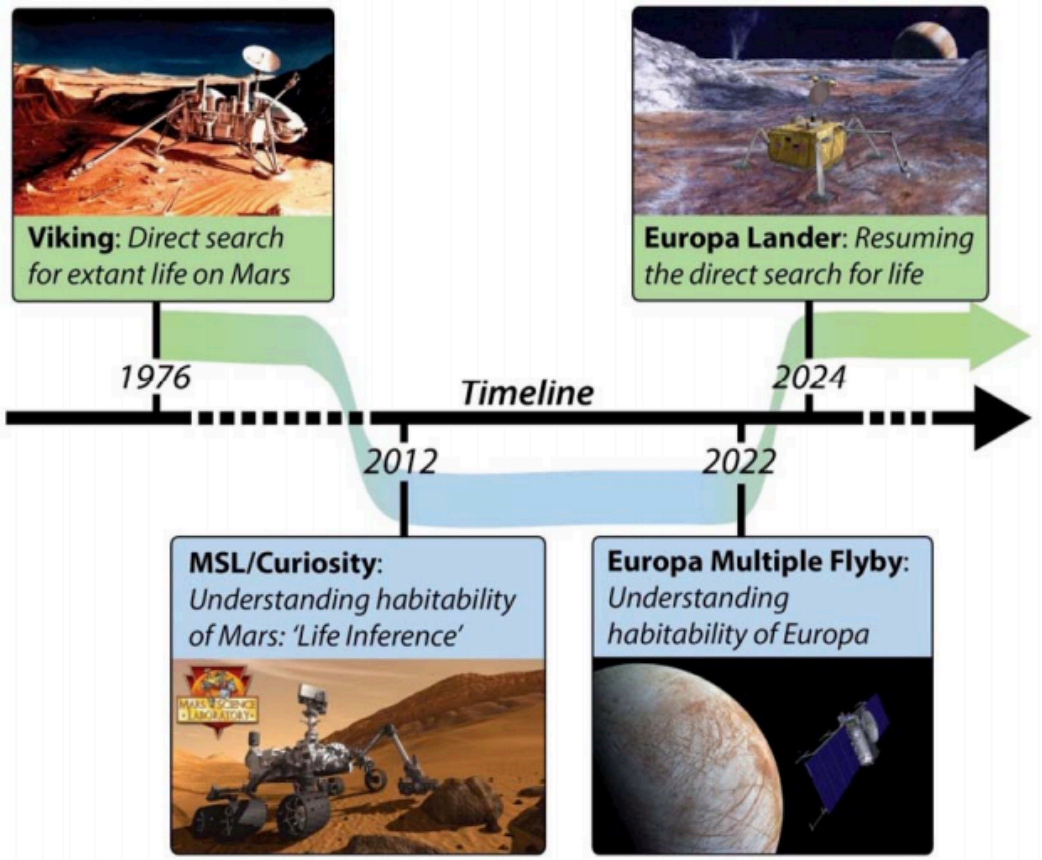
Jet Propulsion Laboratory (JPL) / California Institute of Technology

Image Credit: NASA/NASA JPL

NASA Directing Their Search for Life Towards Ocean Worlds

Water in our Solar System



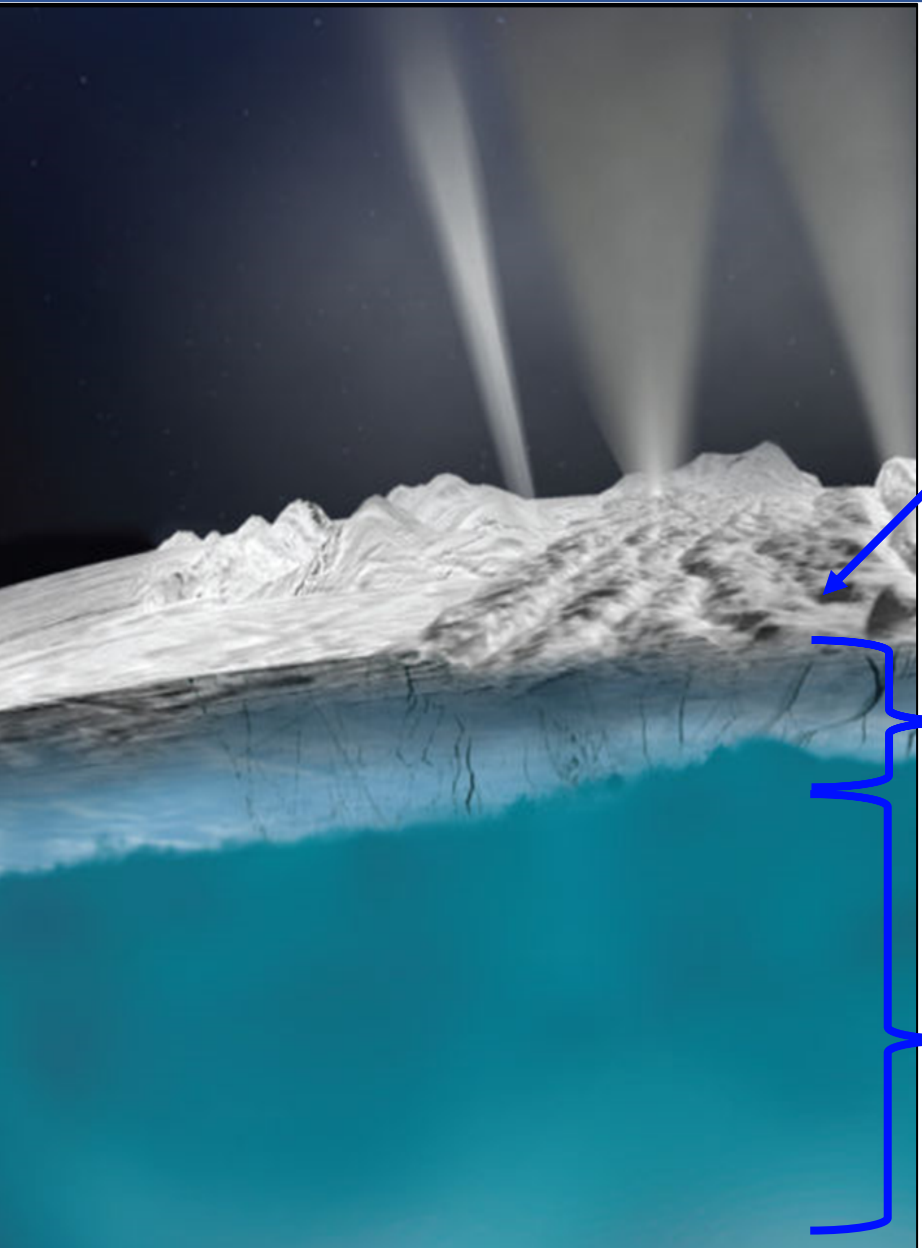


Europa Lander Concept

Predecisional information, for planning and discussion only

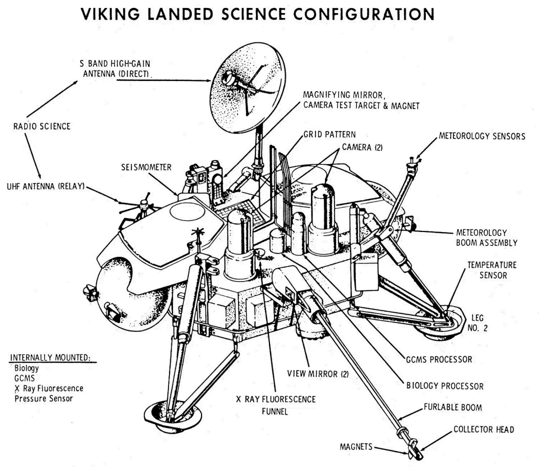
Image Credit: NASA/NASA JPL

Science by Depth: the Surface, Ice Shell, and Ocean



Location	Geodynamics	Habitability and Geochemistry	Life Detection
Near-Surface	Confirm whether diurnal tidal forces cause activity on faults, cracks, and/or through mass wasting.	Characterize the surface processed material, the depth to which it extends, and determine dominant mixing processes.	Identify potential biomarkers and biosignatures within ice grain boundaries at the cavity wall and within the melt water.
Ice Shell	Confirm whether the ice shell interior is convecting or conductive, as well as the amount of tidal heat dissipation and the presence of partial melts.	Measure the variations in non-ice composition with depth and chemical potentials within the ice.	Identify potential biomarkers and biostructures within ice grain boundaries at the cavity wall and within the melt water.
Ocean	Determine the geometry of the interface, and identify any structures.	Measure the ocean composition as a function of horizontal distance and depth from the ocean entry point.	Identify potential biomarkers, biostructures, and motile organisms within the ocean water.

Planetary and NASA Heritage for In Situ Instrumentation



Viking Lander-1975

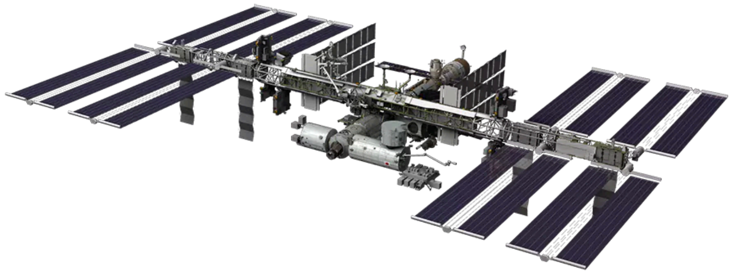
InSight Lander-2018

Artemis Crewed-2028

International Space Station-1998

Mars 2020 Rover

Mars Crewed Late-2030s



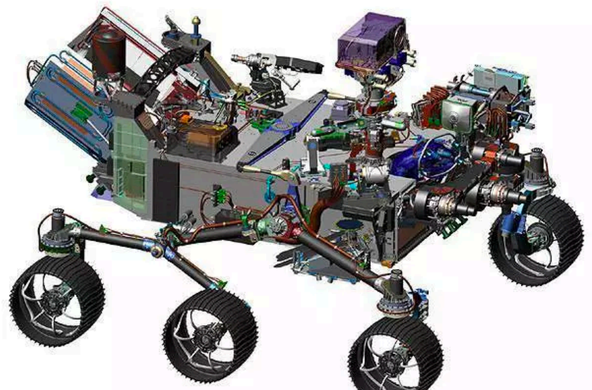


Image Credit: NASA/NASA JPL

Predecisional information, for planning and discussion only

Geologic Activity	Geodynamic State	Mixing and Exchange	Composition and Chemistry	Energy For Life	Physio-chemical Regime for Life	Biomaterials	Life

Geodynamics

Acoustics
Temperature Sensor
Pressure Sensor
Seismometer
Sonar
Engineering Camera
Magnetometer
Chromatography
Ground Penetrating Radar
Strainmeters

Geochemistry

Water Chemistry Sensors: (Pressure, conductivity, temperature, pH, ion selective electrodes, ORP, turbidity, temperature, dissolved gases, specific metals)
Chromatography

Habitability

Water Chemistry Sensors: (Pressure, conductivity, temperature, pH, ion selective electrodes, ORP, turbidity, temperature, dissolved gases, specific metals)
Broad Band Optical Spectra
Chromatography: (CE/LIF or MS, GC/MS, HPLC/LIF or MS)
Multispectral Camera
Deep UV/ Raman

Life Detection

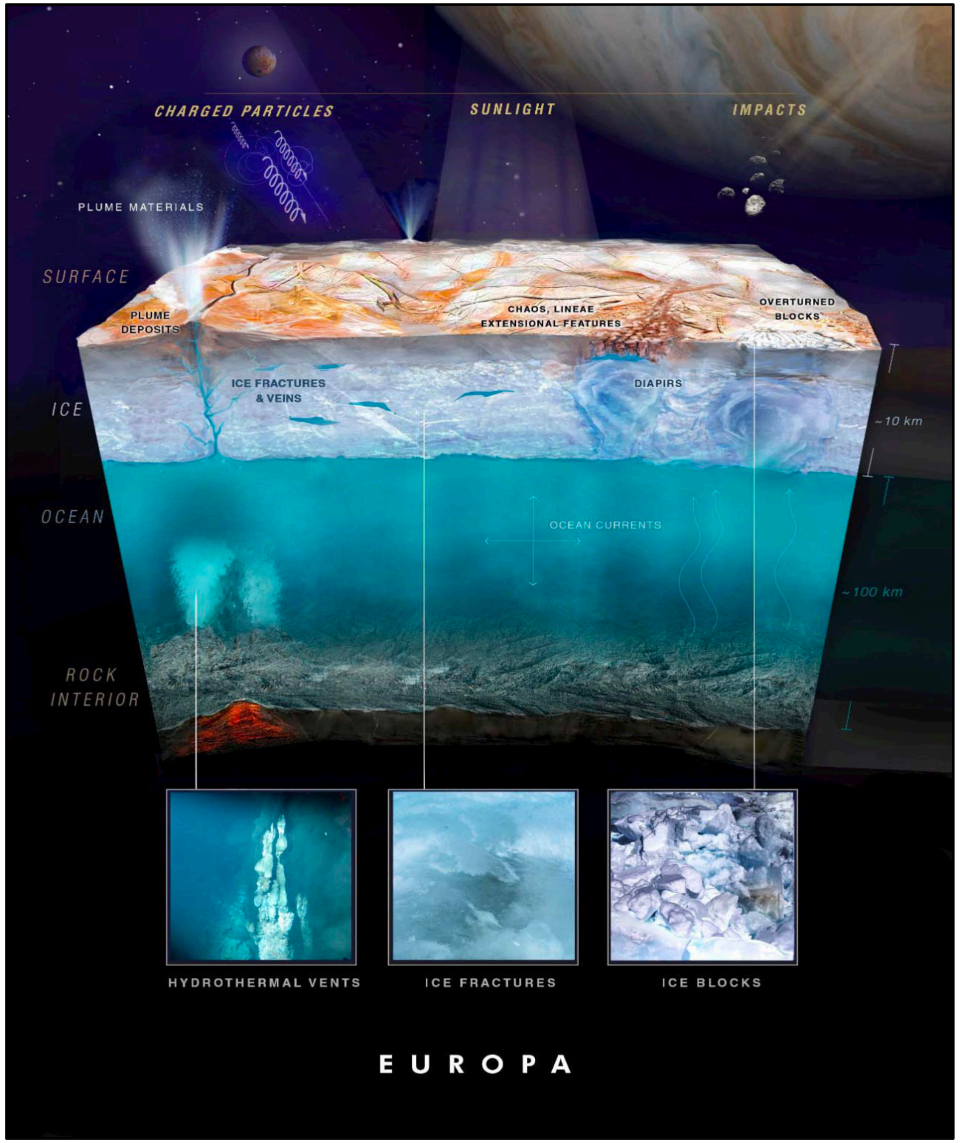
Microscopic Motility Detector
Cell-Flow Cytometer
Broad Band Optical Spectra
Chromatography: (CE/LIF or MS, GC/MS, HPLC/LIF or MS)
Multispectral Camera
Biosignature detection chip/ Fluorescent biosensors
Deep UV/ Raman

Long term Instrument Development for Ocean Worlds

Subsurface vehicles enable a new capability to continuously sample the external environment and provide geospatial resolution to instrument data

Subsurface Instrument Design Considerations

1. Mass, Power, and Volume Requirement
2. Mission Duration
3. Optimal Storage Conditions
4. Operational Lifetime
5. Calibration Mechanisms
6. Instrument Redundancy
7. Sample Preparation
8. Environmental Variation
9. Instrument Specificity
10. Planetary Protection and Contamination Control



How do we Address Life Detection on Ocean Worlds?

Ladder of Life Detection

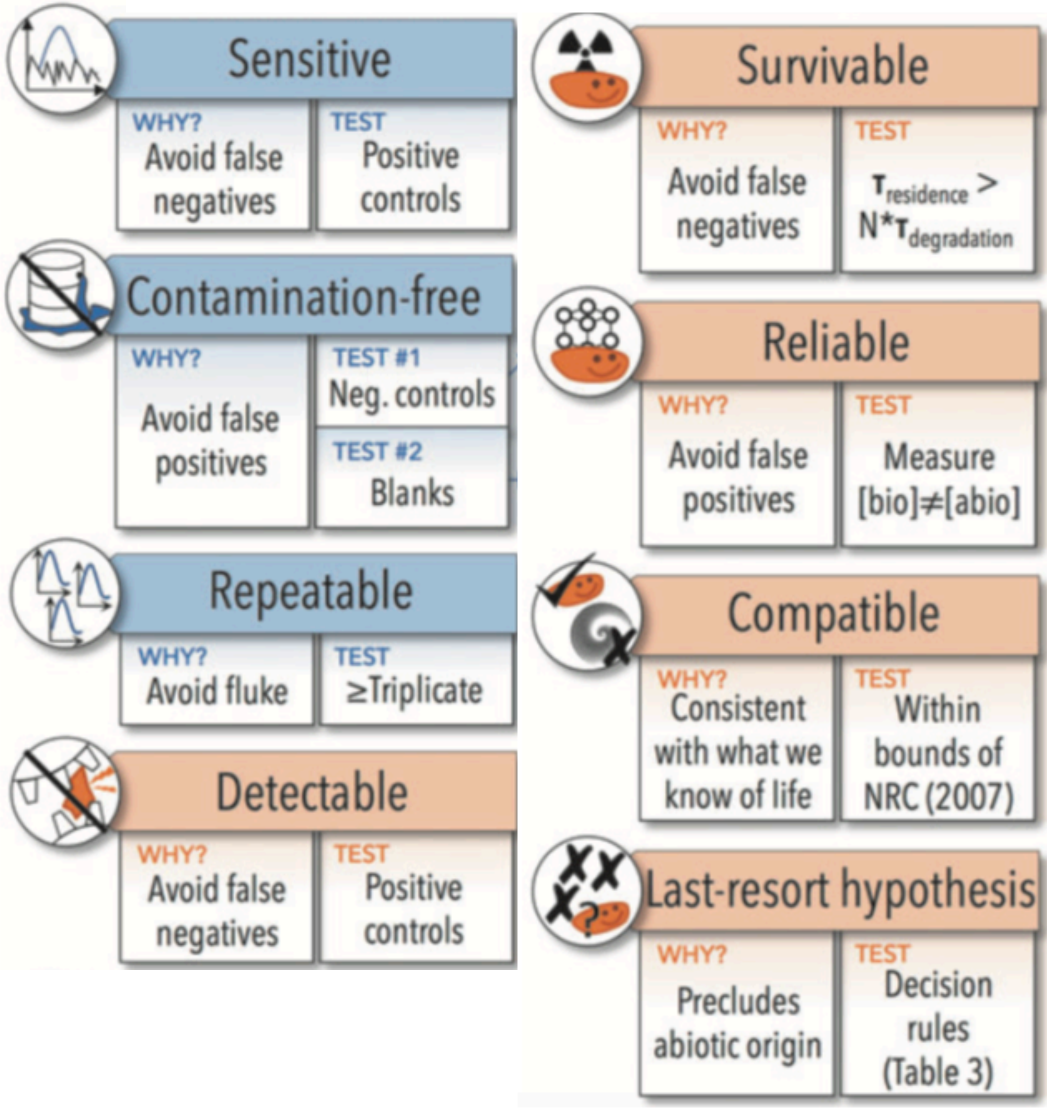
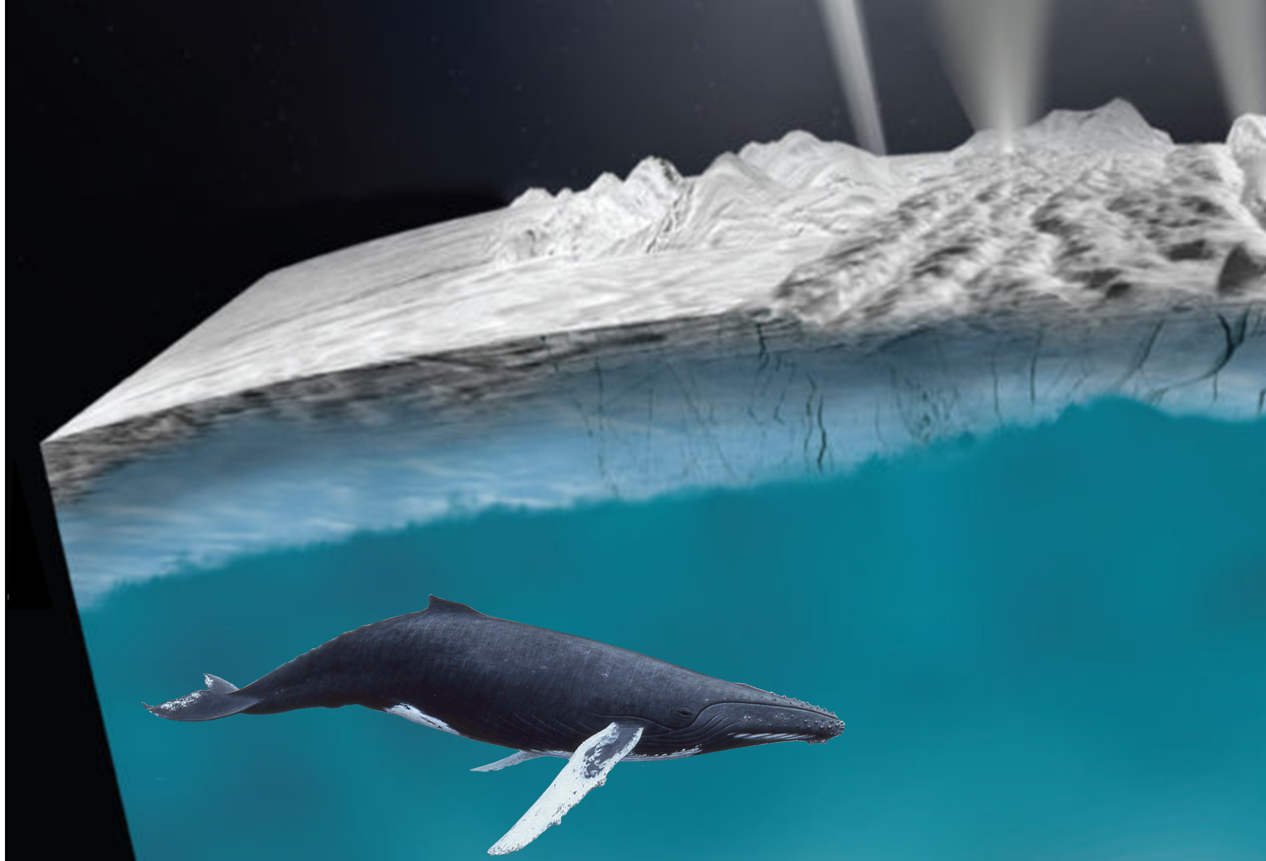


Image Credit: Nevue et. al. 2018

1. Characterize Environment
2. Find "Suspicious Biomaterials"
3. Image/Identify Macro or Microorganisms



Artist's Concept

In designing in situ analytical instruments, several areas need to be addressed

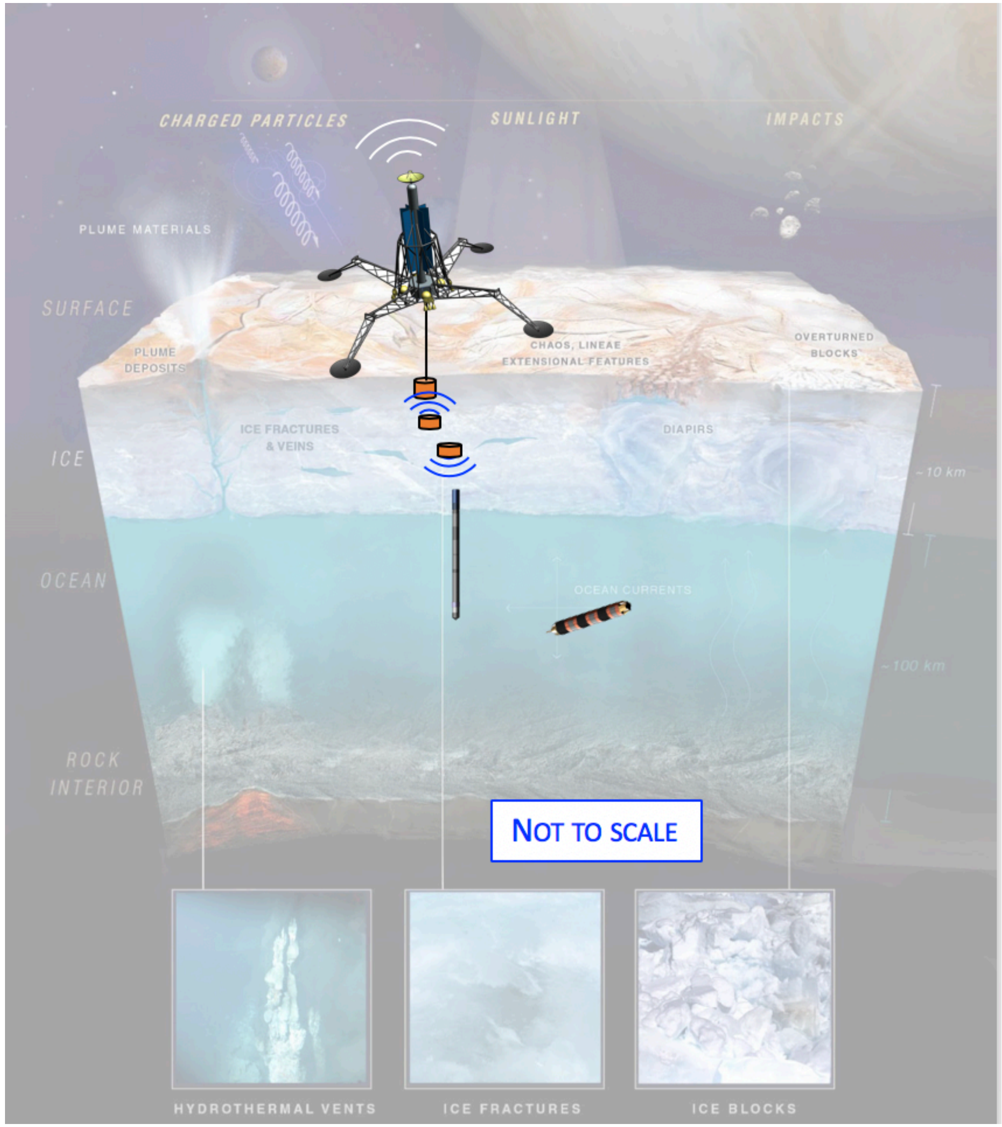
Mission Implications

Mission Duration and Phases

- ~12-15 years to Ocean from Launch
  - Penetration through ice shell
  - Exploration of sub-ice ocean

Instrument Requirements

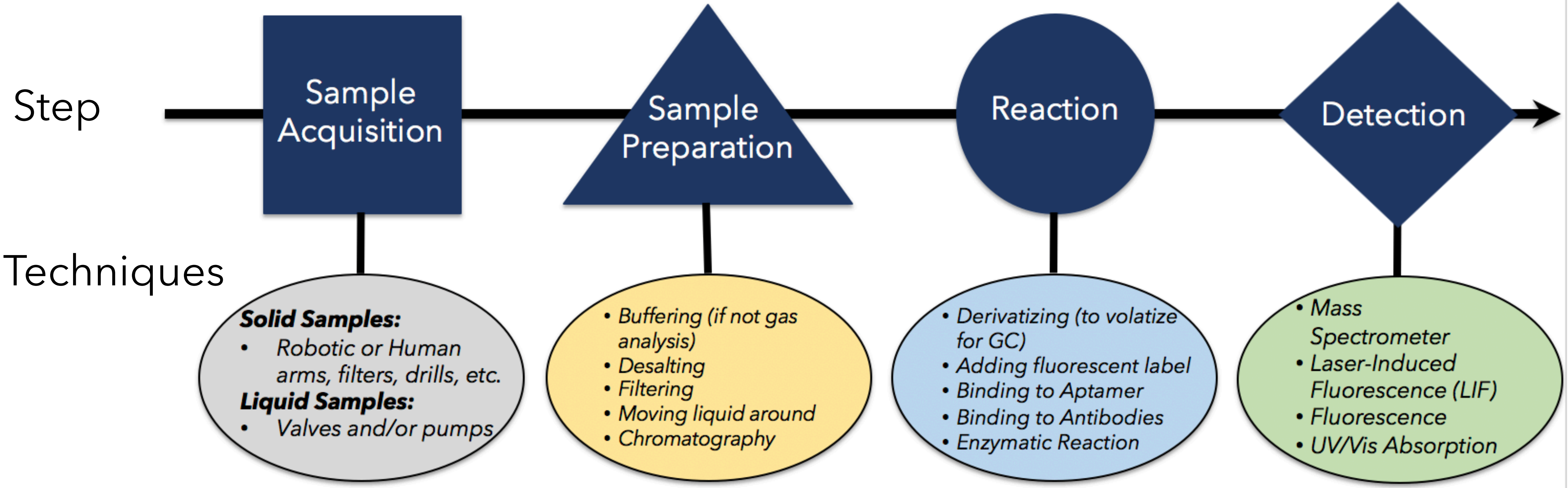
- Triage verses Sampling Instruments
  - Number of sampling events and data prioritization
- Consumables
  - Solvents, dyes, carrier reagents
  - Component lifetimes
- Calibration
  - Solvent injection
  - Electrical drift



Artist's Concept

In designing in situ analytical instruments, several areas need to be addressed

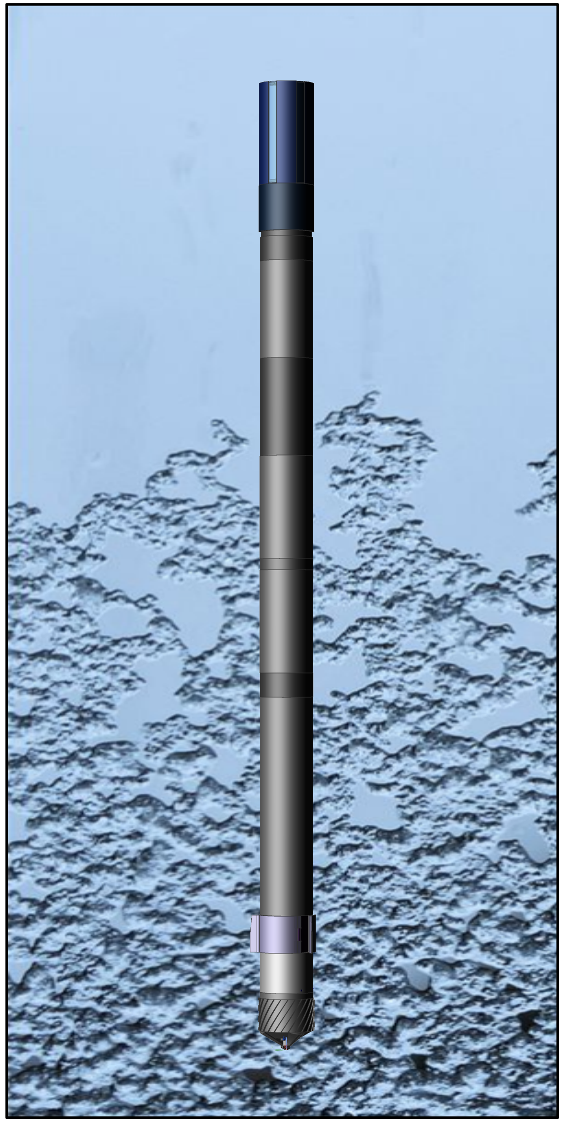
Sample Preparation



In designing in situ analytical instruments, several areas need to be addressed

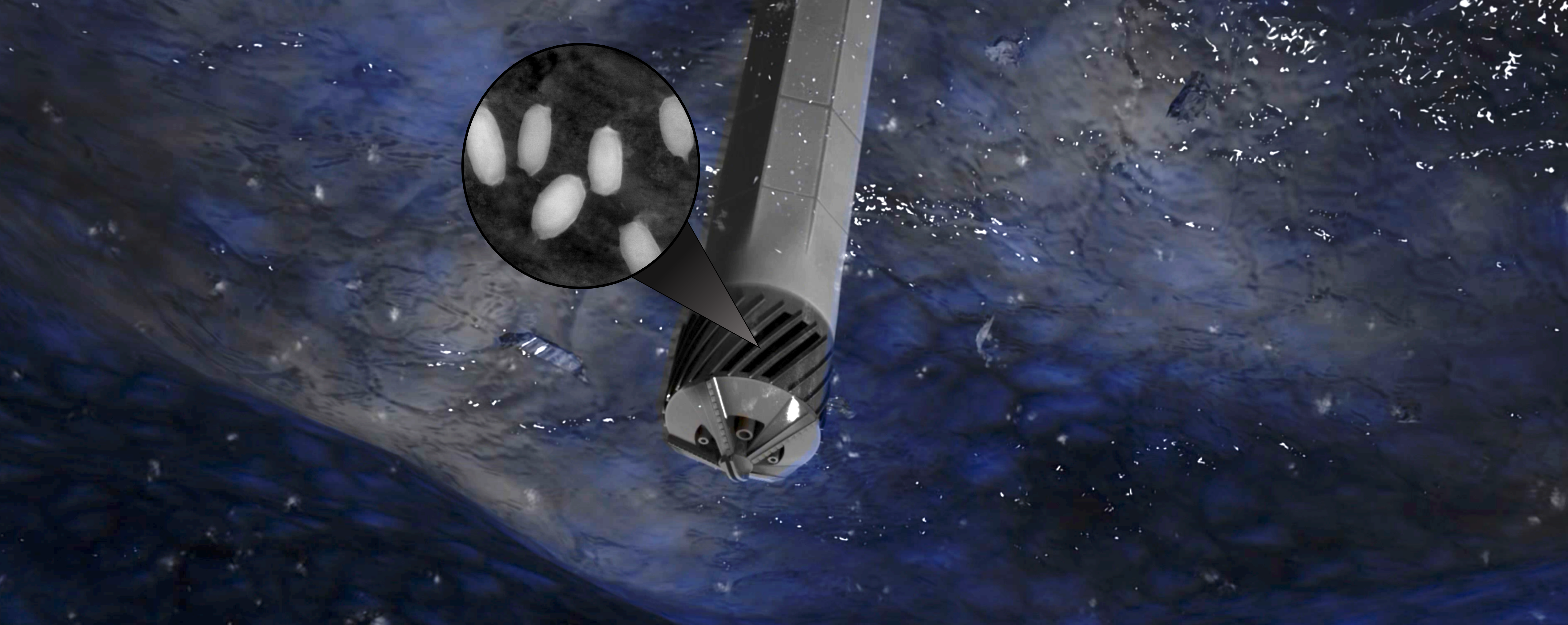
Operational and Sample Conditions

- Sample: Melt will be aqueous while optical instruments may be outward looking into the ice
  - Varying levels of salinity, pH, and TDS
- Size: Pressure vessel diameter >30 cm and payload bay length will be constrained
- Pressure: High, estimated up to 130-260 MPa
  -Pump-down problem
- Temperature: Varying by depth, liquid during penetration and ocean sampling
- Power: Some fraction of the 50kW reactor power
- Data Volumes: Imaging and continuous sampling will reduce the available data volume for additional instruments.
- Vibrational Constraints: Drilling and water-jetting events



Artist's Concept

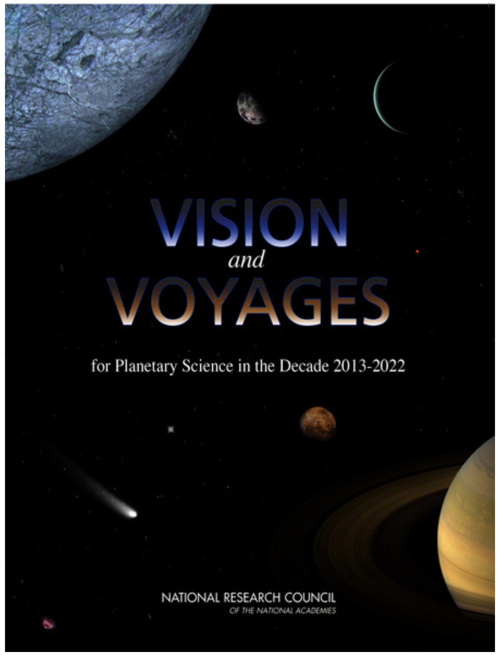
Planetary Protection (PP) ensures that spacecraft meet stringent cleanliness requirements to prevent forward and backward biological contamination

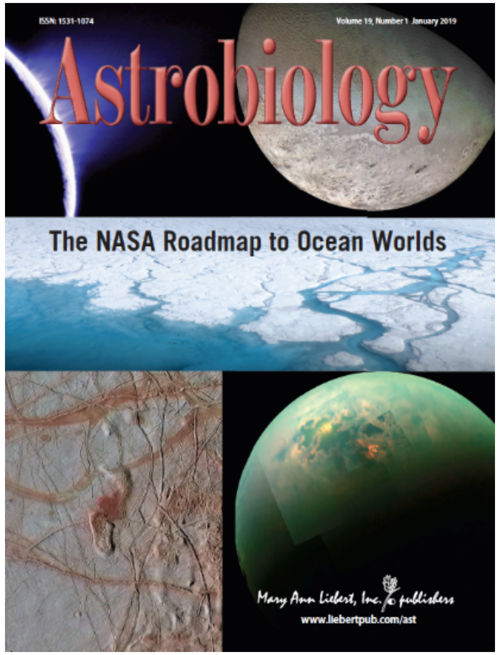


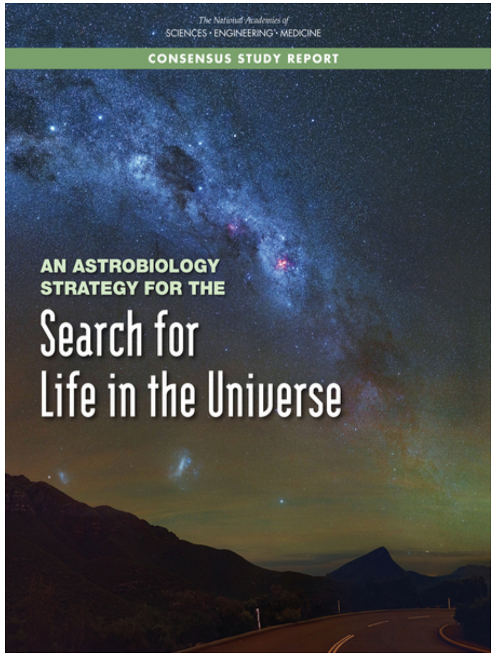
Artist's Concept

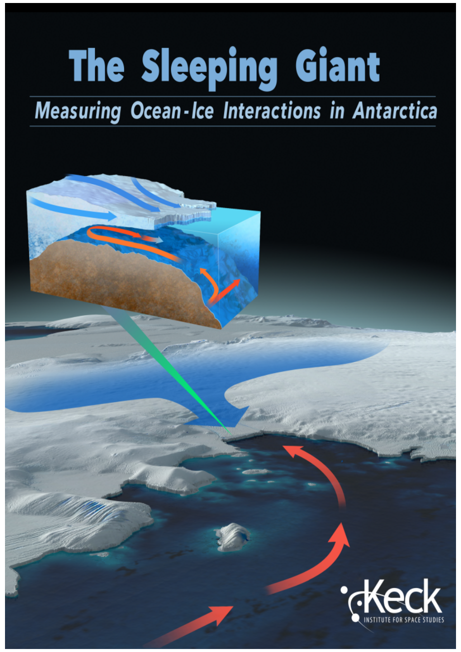
Image Credit: NASA/NASA JPL

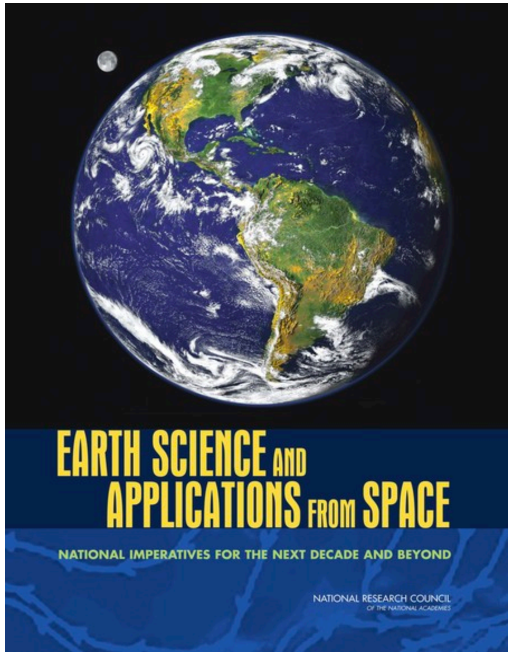
Science Community to Provide Roadmap to Ocean Worlds











NASA

NSIDC
National Snow and Ice Data Center

Thank you to the CHROWE Team

(Cryo-Hydro Robot for Ocean World Exploration)

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